

IN SITU SPECTRAL PROPERTIES (REFLECTANCE AND FLUORESCENCE) OF BENTHIC SUBSTRATES AND ORGANISMS

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LONG-TERM GOALS

The long-term goal of this research is to gain an understanding of the nature and significance of fluorescence phenomena (particularly non-chlorophyll in origin) in benthic marine organisms in general, and coral reef cnidarians in particular.

SCIENTIFIC OBJECTIVES

There were two general goals for this project: (1) investigation of the spectral properties of benthic marine organisms, especially the fluorescence of corals; and (2) data collection to support an improved understanding of the performance capabilities and limitations of the Fluorescence Imaging Laser Line Scan (FILLS) system.

A summary of much of the work carried out under this project was provided in last year's annual report. Much of the follow-on data analysis was carried out under a new grant and is summarized in the annual report for that project (N000149710041). The effort for the remainder of this grant focused on investigation of the contribution of fluorescence to the apparent reflectance signature of corals. This contribution is sometimes apparent to the eye and at other times is detectable by spectroradiometric instruments.

APPROACH

Quantitative in situ fluorescence and reflectance spectra were collected with the diver-operated Benthic SpectroFluorometer (BSF) (Mazel, 1997b). For reflectance measurements a Spectralon® surface was used as a reference. Additional measurements were made in the laboratory after the field season from coral specimens acquired from an aquarium supply company. Fluorescence excitation and emission spectra were collected with a SPEX Fluoromax-2 spectrofluorometer either on shipboard or in the laboratory. Data were examined for evidence of the contribution of the fluorescent pigments to the fluorescence and reflectance spectra.

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A MATLAB program was created that takes as inputs the fluorescence excitation spectrum, fluorescence emission spectrum, reflectance spectrum, and fluorescence efficiencies for the various pigments (Mazel, 1997a). The program will then compute the expected signature of reflected plus fluoresced light that would be measured for any arbitrary irradiance spectrum incident on the surface.

The general mathematical algorithm used in the program arose out of earlier work (Mazel, 1993). The model is being refined in collaboration with Robert Maffione as part of the Coastal Benthic Optical Properties (CoBOP) Departmental Research Initiative (DRI). It is being developed rigorously, starting from first principles, but will be carried through to a simplified formulation that utilizes quantities that are practical to measure in the field.

WORK COMPLETED

Data have been collected that clearly demonstrate the contribution of fluorescence to apparent reflectance. The MATLAB routines for modeling fluorescence contribution under arbitrary irradiance have been completed. A first draft of the refined model for reflectance including inelastic effects has been written.

RESULTS

Figure 1 shows the effect of addition of a fluorescent pigment on the reflectance spectrum of a coral. The measurements are from a coral grown under high illumination in an aquarium. The surfaces that were exposed to strong light exhibited a distinct orange fluorescence, while shaded portions did not. Reflectance spectra were measured from the fluorescent (—) and non-fluorescent (---) areas using a broadband illumination source. Excitation (o) and emission (•) spectra were measured for the fluorescent pigment. They are shown in the figure at an arbitrary scale. The inclusion of the fluorescent pigment has two distinct effects on the reflectance spectrum: 1) an increase in apparent reflectance at the wavelengths corresponding to the emission peak (575 nm); and 2) a decrease in apparent reflectance at the wavelengths corresponding to the two excitation peaks (506 and 555 nm). The absorption spectrum for a fluorescent pigment corresponds to its excitation spectrum, and the increased absorption is clearly seen.

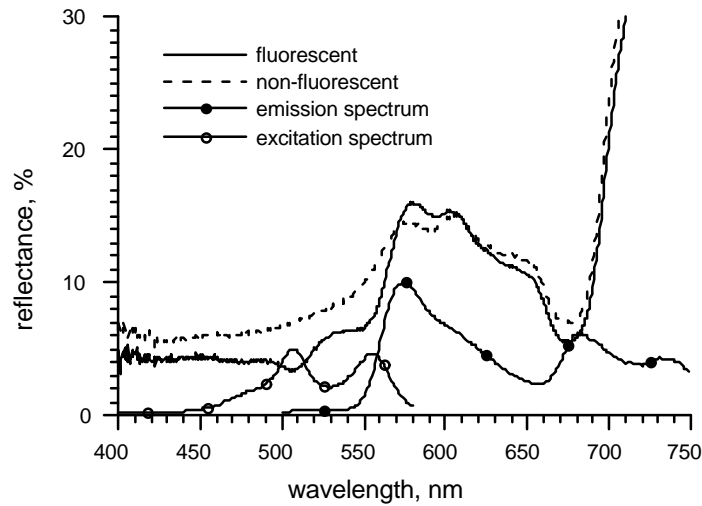


Figure 1

Figure 2 shows an output of the MATLAB model for fluorescence contribution to reflectance. The solid line is in situ BSF measurement of light reflected from the surface of a coral at a depth of 18 meters in the Dry Tortugas. The peak at 685 nm is produced by fluorescence from chlorophyll in the coral's zooxanthellae. The dashed lines represent the modeled chlorophyll emission for four different fluorescence efficiencies: 0.4, 0.6, 0.8 and 1.0 percent. The model uses a prototype chlorophyll emission spectrum and the actual emission in this case has a slightly different profile.

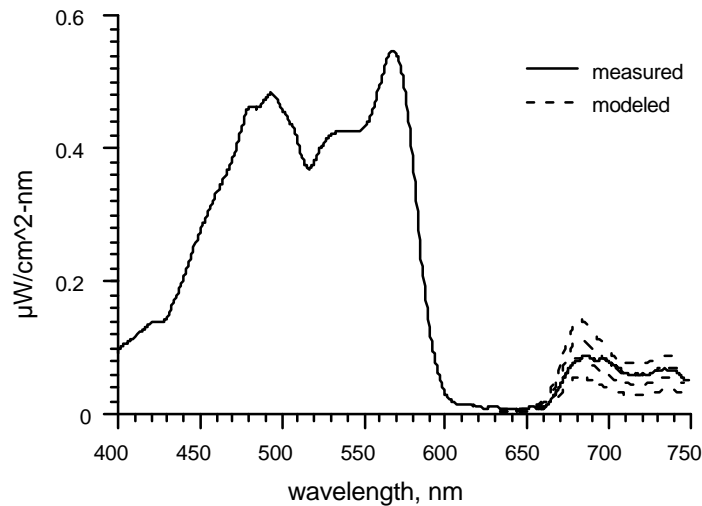


Figure 2

IMPACT/APPLICATIONS

The results have direct application to efforts underway in the new CoBOP DRI. The model that is being developed for reflectance including inelastic effects will be used both as a guide for measurements to be made, and as a tool for interpreting data from the Fluorescence Imaging Laser Line Scanner (FILLS) (Strand, 1997) and from NRL's Portable Hyperspectral Imager for Low Light Spectroscopy (PHILLS), an airborne passive remote sensing system.

TRANSITIONS

Fellow CoBOP researcher Robert Maffione is collaborating on refinement of the original simplified mathematical model for quantifying and predicting enhancement of the apparent reflectance of benthic organisms by fluorescence. The model being developed will have general application to the investigations being carried out as part of the overall CoBOP project.

RELATED PROJECTS

This project is one of several that were carried out as part of the CoBOP 1996 field campaign. Other researchers participating in the program include Drs. Ken Carder, Charles Yentsch, and Michael Lesser. The data collected through this grant are being used by them wherever there are direct overlaps.

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<http://nightsea.mit.edu/research/cobop/cobop.html>